Technical Change and Efficiency Measures: The Post-Privatisation in the Gas Distribution Sector in Argentina

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Abstract: In this paper we use a stochastic frontier approach to analyse the technical change in the post-privatisation period in the gas distribution sector in Argentina. We found that there are both a catching up effect and a shift in the frontier that are showing that the sector as a whole improved its efficiency in the reviewed period. Moreover, this phenomenon holds not only for the average but also for every firm in the sample.

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Technical Change and Efficiency Measures: The Post-Privatisation in the Gas Distribution Sector in Argentina

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I. Introduction

The distribution of natural gas in Argentina began its activity in 1952 with the creation of Gas del Estado (GDE). Since the beginning, GDE had the monopoly in all the stages of the transport, distribution and marketing of natural gas. This company was privatised in 1992, being fractionated into two transport and eight distribution companies, which operate as geographical natural monopolies. The regulation of the monopolistic stages of the industry is defined in the regulatory frame Law 24076 under the supervision of ENARGAS, the regulatory agency of the gas sector.

Behind the privatisation of GDE was the idea that private firms could improve the efficiency of the sector. This paper addresses this issue by analysing both technical change and catching up effects over the post-privatisation period, 1993-1997. We chose a period of five years since privatisation because the industry is regulated with an RPI-X+K mechanism with reviews every five years. In that way, we are analysing all the period since the privatisation until the first review.

Gas distribution in Argentina is a regulated activity with companies facing an obligation to supply all demand in their concession area. Since production levels are exogenous to the firm, the objective function for the firms is to minimise costs subject to achieving an exogenously determined product level. Under the prevailing arrangement, the preferred model is usually a cost one. However, since there are not regulatory accounting guidelines in the sector, the cost comparisons are not always easy. Moreover, current firms did not make many of the decisions about capital investments (some investments are mandatory

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and others were made by GDE) and, therefore, the concept of allocative inefficiency becomes diffuse. Finally, though the firms are obliged to supply all demand that is connected to the network, they can expand the network in order to increase their demand. In that way, demand is not completely exogenous.

The rest of the paper is organised as follows. Section 2 presents the theoretical structure of the production function model estimated. Section 3 presents the data and empirical results for the post-privatisation period 1993-1997. Section 4 analyses the returns to scale and the overall technical change in the gas distribution sector. Both neutral and non-neutral technical changes are considered. Section 5 concludes.

II. The model

The stochastic frontier production function model with panel data is written as

$$Y_{it} = \beta_0 + X'_{it}\,\beta + \varepsilon_{it},$$

where Y_{it} is the output of decision making unit (DMU, hereafter) i (i=1, 2,...,N) at time t (t=1,2,...,T), X_{it} is the corresponding matrix of k inputs and β is a kX1 vector of unknown parameters to be estimated. The error term is specified as

$$\varepsilon_{it} = v_{it} - u_{it}.$$

The v_{it} are statistical noise and are assumed to be independently and identically distributed, while u_{it} are non-negative random variables which represent technical efficiency. The v_{it} represent those effects that cannot be controlled by the DMU, such as measurement errors, omitted variables and weather conditions. Technical efficiency, on the other hand, accounts for those factors that can be controlled by the DMU, and can be defined as the discrepancy between a DMU's actual output and its potential output. We use the Battese and Coelli (1992) representation for the technical efficiency term:

$$u_{it} = \exp[-\eta(t-T_i)]u_i \quad (1),$$

where η is a parameter to be estimated and u_i are assumed to be i.i.d. as truncations at zero of the $N(\mu,\sigma^2)$ distribution. The level of technical efficiency of DMU i in period t is obtained as

$$EF_{it} = \exp(-u_{it}).$$

Battese et al. (1992) show that the best predictor of $\exp(-u_{it})$ is obtained by using the conditional expectation of $\exp(-u_{it})$ given ε_{it}, $E[\exp(-u_{it})/\varepsilon_{it}]$.

In this specification, since the exponential function, $\exp[-\eta(t-T_i)]$, has a value of one when t=T, the random variable u_i can be considered as the technical inefficient effect for the i-th DMU in the last period of the panel. For earlier periods, the technical efficiency effects are the product of the technical inefficient effect for the i-th DMU in the last period of the panel and the value of the exponential function, whose value depends on the parameter η and the number of periods before the last period of the panel. If η is positive then the model shows decreasing inefficiency effects, while if η is negative the inefficiency effects are increasing (Coelli et al. 1998). A disadvantage of this specification is that the ordering of the firms according to the magnitude of the technical inefficiency effects is the same at all time periods. The main advantage, at least for our purposes, is that the technical inefficiency changes over time can be distinguished from technical change. The latter is obtained including a time trend (and eventually its square) in the regressor vector.

It is worthwhile noting that we utilise the parameterisation of Battese et al. (1977) who replace σ_v^2 and σ_u^2 with $\sigma^2=\sigma_v^2 + \sigma_u^2$ and $\gamma=\sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. The parameter γ must lie between zero and one. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency. This specification allows us to test the null hypothesis that there are no technical inefficiency effects in the model, H_0: $\gamma=0$, versus the alternative hypothesis H_1: $\gamma>0$.

The imposition of one or more restrictions upon this model can provide a number of special cases. Setting μ to be zero reduces to the traditional half-normal model. Furthermore, restricting η to be zero provides the time-invariant model set out in Battese et al. (1989).

In this paper we test the half-normal distribution hypothesis vis a vis the more general truncated normal distribution, and we also contrast the hypothesis that the efficiency is time invariant. In addition, we test the null that there was no technological change in the five year post-privatisation period, 1993-1997.

III. Empirical results

The model presented in section II is used to estimate the production frontier, the time-varying technical inefficiency and the technical change of the eight geographical natural monopolies observed during the first review period.

The first important decision we have to make was the choice of the variables to include in the model. Neuberg (1977) describes four related but distinguishable activities in electricity distribution that can be assimilated to the gas case. Firstly, distribution properly which includes maintenance of equipment and installations to users and load dispatch. Secondly, meter reading and billing. Thirdly, sales including related activities such as publicity and fourthly administration. Neuberg suggests four variables as main cost drivers in electricity distribution: number of customers served, total KWh sold, Km of distribution lines and Km2 of distribution area. Burns et al. (1994) add some additional variables: maximum demand (which determines system configuration and size), transform capacity (which affects losses) and demand structure (which determines load factors at different moments of the day).

The main conceptual problem is to identify within this set of variables which one or ones are the output. Neuberg discards the possibility of treating distribution companies as multiproduct firms given that the different variables cannot be separately sold and/or priced. For example, once the number of clients is identified as the product (with a price equal to average annual revenue per customer of the firm), energy sales in (KWh) cannot be sold separately. We follow Neuberg who chooses the number of customers served as the relevant output in a single output specification.

The data set is an unbalanced panel of the eight DMU observed over five years (1993-97). The information corresponds to December of each year. The set includes information about one output, two inputs and three environmental variables. The variables are: number of customers (CUSTOM, the output), kilometres of pipes (KMNET, a proxy of capital input), number of employees (EMPL, the labour input)[1], concession area (AREA), market structure (the ratio of residential sales to total sales, STRUCT) and maximum demand (MAXDEM). The last three are environmental variables and are introduced in the model as firm specific characteristics that allow inter firm comparisons. In this way, a DMU cannot appear to be efficient simply by virtue of the fact that its operating environment differs widely from that of all the other firms in the sample. The model also includes a time trend.[2]

All of the used data is in the public domain. The number of clients, total sales, residential sales and distribution network, were provided by the ENARGAS. Sales are in MM m3/day (9300 Kcal). The maximum demand was obtained as the ratio of the month with maximum demand to the number of days in that month. The concession area was calculated using data provided by INDEC (National Bureau of Statistics). The labour data was obtained from the balance sheets of the firms. The omitted data corresponds to number of employees of Gasnor and Litoral Gas for 1997 (2 observations).

The summary statistics of the raw data are presented in table 1 of Appendix.

We begin the estimations with a flexible model, and we test the different specifications.[3] First we test the null that the efficiency term has a half-normal distribution. The null that the inefficiency effects are time invariant is also tested. In both cases we use a Likelihood Ratio (LR) test. This test is based on the log-likelihood functions as follows:

$$LR = -2[L_R - L_U],$$

where L_R is the log-likelihood of the restricted model and L_U is the log-likelihood of the unrestricted model. The LR statistic has a chi-square distribution with degrees of freedom equal to the number of restrictions involved (in our three tests, one).[4]

In a first step we test the null that there are not technical inefficiency effects in the model. The log-likelihood function for the maximum likelihood (ML) model is calculated to be 78.50, and the value for the ordinary least squares (OLS) fit of the production function is 42.17, which is significative less than the former. Since the LR statistic is greater than the critical value (one degrees of freedom), the null hypothesis of no technical inefficiency in the gas distribution in Argentina is rejected. The ML estimate for γ is 0.99 with estimated

[1] A potential problem will arise if some firms subcontract some activities (such as cleaning and maintenance) and others not.

[2] Burns et al. (1998) estimate a cost function for the British Gas regions. They include a time trend as a proxy for technical progress but they found that it was insignificant.

[3] Since the sample is not large enough, we cannot contrast a Cobb-Douglas versus a translog specification. As Coelli et al. note, the translog estimates are likely to suffer from degrees of freedom and multicollinearity problems resulting in inefficient estimates.

[4] It must be noted that the critical value for a test of size α when the null is $\gamma=0$ and the alternative is $\gamma>0$, is equal to the value of the chi-square for a size of 2α.

standard error of 0.0004. These results are consistent with the conclusion that the true γ-value is concluded to be greater than zero.

The next step is to test the half-normal model versus the alternative truncated normal. The estimated value of μ is 0.29, and the log likelihood function of the unrestricted model is 79.42, which is not significative different from 78.50, the log likelihood of the restricted (μ=0) model. Since we cannot reject the null, in the final model the efficiency component is assumed to have a half-normal distribution.

Finally, we test the time invariant inefficiency effect hypothesis. We do so by running two models, one with the parameter η and another without it. The log likelihood of the unrestricted model is 91.19, which is significative greater than the log likelihood of the restricted (η=0) model. Since the LR test rejects the null H_0: η=0, we include η in the model.

The estimated production function is[5]:

$$\text{Ln CUSTOM} = \beta_0 + \beta_1 \text{ Ln KMNET} + \beta_2 \text{ Ln EMPL} + \beta_3 \text{ Ln AREA} + \beta_4 \text{ Ln MAXDEM} + \beta_5 \text{ Ln STRUCT} + \beta_6 \text{ TIME} \qquad (2)$$

We include a time trend in the model to account for technical change.[6] The specification assumes a half-normal distribution of the efficiency effects, and the non-negative random variables that represent technical efficiency are assumed to follow the representation shown in (1).

The OLS, COLS (corrected OLS) and ML estimates of the production function are presented in table 2 in appendix.

IV. Returns to scale and technical change

Returns to scale (RTS) are usually calculated from the sum of the inputs' coefficients as:

$$\text{RTS} = \beta_1 + \beta_2 = 0.248 < 1.$$

However, it is sometimes noted that when the model includes environmental variables the scale elasticity is given by the proportionate effect on production of changes in the input

[5] The computer program FRONTIER 4.1, developed by T. Coelli (1996), is used for estimations.
[6] It is worthwhile noting that in many applications it is included a time trend and its square. This is done when the estimated production function is a translog one, in order to provide consistency with the second order approximation notion of the translog form.

variables and the environmental variables. The main point is that changing the scale of a firm would involve changing all of these characteristics of customers and network (Burns et al., 1994). In this case,

$$RTS = \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 = 0.3488 < 1.$$

These results are puzzling, since the industry is usually assumed to have economies (or at least constant) of scale. However, it is important to notice that, though in the ML specification there are important diseconomies of scale, this is not longer true in the OLS model.[7] Why do the OLS model always estimate greater returns to scale than the ML one? To answer this question one must recognise that the ML model estimates the slopes parameters of the frontier giving more importance to the efficient DMU. OLS, on the other hand, estimates these parameters by giving the same weighting to all the observations. Since the network investments are sometimes mandatory, it seems natural that the efficient firms have inputs elasticities less than the inefficient ones, because these investments are not so productive, in terms of new customers, as the investments of the less efficient companies.

The null that there was not technical change is tested using a LR test. We do so by running two models, one with time trend and another without time trend. The log likelihood of the unrestricted model is estimated to be 91.19, while the restricted model has a log likelihood of 89.46. Since the LR test rejects the null H_0: t=0, we conclude that there is technical change in the post-privatisation period.

Given the estimated parameters of the ML model, the overall rate of technical change is obtained as the derivative of the logarithm of the production function with respect to time, dy/dt, which in this case is equal to β_4.[8]

$$\delta \text{ Ln CUSTOM}/\delta \text{ TIME} = 0.0082.$$

The above number (0.82%) is interpreted as a constant annual growth rate. The inclusion of time in the manner depicted in equation (2) accounts for what is known as Hicks-neutral technical change. That is, the functions shift their constant terms but their slopes do not

[7] In the OLS specification, we cannot rejected the null that $\beta_1 + \beta_2 = 1$.
[8] In a translog specification with time and time square, the neutral technical change is simply $dy/dt = \beta_i + 2\beta_j t$, where β_i and β_j are the coefficients associated with time and time square, respectively.

alter.[9] Non-neutral technical change, on the other hand, can be accounted for by also including terms involving the interactions of the inputs and time:

$$\text{Ln CUSTOM} = \beta_0 + \beta_1 \text{ Ln KMNET} + \beta_2 \text{ Ln EMPL} + \beta_3 \text{ Ln AREA} + \beta_4 \text{ Ln MAXDEM} + \beta_5 \text{ Ln STRUCT} + \beta_6 \text{ TIME} + \beta_7 \text{ TIME} * \text{Ln KMNET} + \beta_8 \text{ TIME} * \text{Ln EMPL}$$

The OLS, COLS and ML estimates of the preferred model are presented in table 3 (see Appendix).

The input elasticities are no longer constant. The output elasticity with respect to labour is now

$$\delta \text{ Ln CUSTOM}/\delta \text{ Ln EMPL} = \beta_2 + \beta_8 \text{ TIME},$$

and the output elasticity with respect to capital is

$$\delta \text{ Ln CUSTOM}/\delta \text{ Ln KMNET} = \beta_1 + \beta_7 \text{ TIME}.$$

Since in the ML preferred model β_7 (β_8) is positive (negative), the elasticity with respect to capital (labour) is increasing (decreasing) over time. That is, the capital share is increasing.

The technical change is also analysed from a stochastic parametric Malmquist index approach. Estimating stochastic parametric distance functions and Malmquist indices has some advantages with respect to deterministic, parametric or non-parametric approaches: several hypothesis can be tested, such as statistical significativity of parameters or returns to scale. They also present some potential shortcomings, especially if the translog specification is used. In this case, regular conditions on the production function are not guaranteed and must be checked, especially convexity on outputs and concavity on inputs (Fuentes et al., 1998).

The Malmquist index construction allows us to decompose the secular productivity into frontier shifts effects and catching up effects. These indices are calculated using the stochastic frontier of section 3, by using the following formulae:

$$\text{Efficiency change} = EF_{it}/EF_{is}. \quad (3)$$

Since in our preferred model the variables of interaction are significative, we can reject the null of neutrality (if we cannot reject the null then the technical change can simply be calculated doing the first derivative of the production function with respect to time, at a particular data point). In this case, the technical index may vary for different input

[9] That is, the marginal rate of technical substitution does not change.

vectors.[10] Coelli et al. (1998) suggest that a geometric mean be used to estimate the technical change index between adjacent periods s and t. That is,

$$\text{Technical change} = \{[1+ \delta f(X_{is},\tau,\beta)/\delta\tau]\times\{[1+\delta f(X_{it},\tau,\beta)/\delta\tau]\}^{0.5}. \quad (4)$$

The first derivative is evaluated at τ=s and the second one in τ=t.[11] The indices of efficiency change (3) and technical change (4) can be multiplied together to obtain a Malmquist index. Table 4 sum up the main results, which are presented in average values per year (see Appendix).

The Malmquist index is on average equal to 1.028. It comes out that over the reviewed period the average productivity growth was rather high (almost 3%). The other two columns in table 4 allow us to analyse the decomposition of the Malmquist indices: technical change is positive, near 2.5% per year, which is combined with a positive rate of technical efficiency of about 3.6% per year. That is, in the period reviewed we observe both a shift in the frontier and a catching up effect.[12]

V. Conclusions

The distribution of natural gas in Argentina was privatised in 1992. Behind the privatisation of GDE was the idea that private firms could improve the efficiency of the sector. In this paper we use a stochastic frontier approach in order to analyse the technical change in this sector in the post-privatisation period. We found that there are both a catching up effect and a shift in the frontier that are showing that the sector as a whole improved its efficiency in the reviewed period. Moreover, this phenomenon holds not only for the average but also for every firm in the sample.

However, in this paper we just present one approach to the estimation of the technical change. In order to make the conclusion more robust, it will be necessary to perform other analyses, such as the estimation of a cost frontier and a Total Factor Productivity (TFP) methodology. NERA (1997), for example, uses a TFP approach to estimate the annual

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[10] It is worthwhile noting that the annual growth rate is now δ Ln CUSTOM/δ TIME = $\beta_6 + \beta_7$ Ln KMNET + β_8 Ln EMPL.

[11] f(.) is the production function and τ is time.

[12] It is worthwhile noting that this catching up effect is observed for every firm and every year of the reviewed period.

technical change in the gas distribution sector in Argentina in the period 1070-1995.[13] They found that the annual TFP measure, using customers as the proxy of output, was 2.38%, a number that it is very close to the one estimated in this paper.

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[13] It is important to notice that the period used by NERA includes the pre-privatisation era.

Appendix

Table 1
Summary statistics

Variable	Sample	Mean	Standard Error
Number of customers	40	635026	521293
Km. of network	40	10639	4544
Number of employees	38	551	338
Concession area (Km^2)	40	301501	244554
Residential sales (MM m3/day)	40	1964	1491
Total gas sold (MM m3/day)	40	8368	4543
Maximum demand (thousand of m3)	40	9417	5307

Table 2
Production function estimates

Variable	OLS	COLS	ML
Constant	6.14 (13.70)	6.22	11.55 (23.21)
Ln EMPL	0.54 (7.05)	0.54	0.22 (4.42)
Ln KMNET	0.37 (6.50)	0.37	0.028 (1.08)
Ln AREA	-0.16 (-12.12)	-0.16	0.018 (0.35)
Ln MAXDEM	0.14 (4.74)	0.14	0.039 (2.08)
Ln STRUCT	-0.16 (-3.72)	-0.16	0.043 (2.47)
TIME	0.0037 (0.32)	0.0037	0.0082 (2.90)
γ		0.8500	0.9999 (78053.50)
η			0.0175 (5.87)
Log-likelihood	42.17		91.19

Between parentheses are presented the t-statistics. Ln stands for natural logarithm.

Table 3
OLS, COLS and ML estimates of the preferred model

Variable	OLS	COLS	ML
Constant	6.45 (11.02)	6.54	13.31 (31.21)
Ln KMNET	0.51 (4.59)	0.51	0.18 (3.87)
Ln EMPL	0.42 (3.28)	0.42	0.096 (4.22)
Ln AREA	-0.15 (–10.78)	-0.15	-0.18 (-28.72)
Ln MAXDEM	0.092 (1.48)	0.092	0.008 (0.32)
Ln STRUCT	-0.16 (-3.73)	-0.16	-0.0073 (-0.52)
TIME	-0.0189 (–0.73)	-0.0189	-0.017 (-2.35)
TIME * Ln KMNET	-0.0046 (-0.20)	-0.0046	0.022 (7.48)
TIME * Ln EMPL	0.011 (0.34)	0.011	-0.026 (-5.79)
γ		0.8500	0.9998 (16520.6)
η			0.0077 (1.84)
Log-likelihood	42.71		102.59

Between parentheses are presented the t-statistics. Ln denotes natural logarithm.

Table 4
Technical efficiency and
Malmquist index decomposition
Average values*

Year	Efficiency Change	Technical Change	Malmquist Index
1994	1.003827	1.023439	1.027355
1995	1.003797	1.024589	1.028480
1996	1.003768	1.025357	1.029220
1997	1.003146	1.024872	1.028096
Geometric Mean	1.003634	1.024564	1.028287
Standard Deviation	0.000326	0.000814	0.000777

*Geometric means. Since the information is from December of each year, there are not estimations for 1993.

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